

# Vision Guidance System for AGV Using ANFIS

Kyunghoon Jung, Inseong Lee, Hajun Song, Jungmin Kim, and Sungshin Kim\*

School of Electrical Engineering, Pusan National University, Busan, 609-735, Korea  
{hooraring, islee, darkhajun, kjm16, sskim}@pusan.ac.kr

**Abstract.** This paper presents a study of vision guidance system of AGV using ANFIS(adaptive network fuzzy inference system). The vision guidance system is based on driving method that recognize obvious characteristic object like driving line and landmark. It has an advantage in its ability to get more data points than other induction sensor of AGV. However, it is hard to build such a system because the camera used for vision guidance system is severely affected by disturbance factor caused by varying brightness of light. Therefore, we have designed and created a dark-room environment to minimize this disturbance factor. However, due to the reduction of viewing-angle by minimized dark-room design, it is difficult to control using PID which is commonly used in driving control, on fast converted driving line. Therefore, this paper proposes vision guidance method of AGV using ANFIS. AGV modeling is done through kinematic analysis for camera and created dark-room environment. Steering angle by double wheel input is revised through FIS. This data is trained by hybrid ANFIS training method, and it is used for driving control. To do performance test of proposed method, we have conducted series of experiments by creating a simulation model of AGV. We also conducted a comparative analysis of proposed method with PID control.

**Keywords:** vision guidance system, AGV, PID, ANFIS, driving control.

## 1 Introduction

AGV is used at various applications to do tasks that are normally hard, even impossible to be completed by human. Due to these particular features, various industrial automation systems use AGV for loading, unloading, transporting and automating various tasks that normally require human intervention. The development of various automation processes and techniques for industrial production particularly reduced the cost associated to distribution of many industrial goods adding an competitive edge to overall production and distribution scheme. The increasing importance of the AGV in industrial applications contributed the growing number of studies for localization and driving control techniques as well as exploring new guidance system technology related to AGV [1-2].

The AGV guidance method, as a key element of AGV technology is divided into two parts: one is wireless guidance method and the other is wired guidance method. In

---

\* Corresponding author.

wireless guidance method, the position of the AGV is calculated by triangulation using the receiver or the transmitter which are installed on the wall, the ceiling and the pillar. However, wireless guidance method is affected by the disturbance element from the environment which introduces the significant level of errors when the receiver or the transmitter processes incoming and transmission signals. Wire guidance method is based on a guided line that is laid on the surface of the floor which the vehicle follows. This method is frequently used in the payload delivery system due to its safety feature. However, the drawback of this method is that it requires the high cost to lay the guiding line. Another drawback of this method is that it has the low-flexibility in reconfiguring itself to adapt to newly changed environment - the guide line needs to be laid again according to new path configuration. Recently, there are growing interests in finding new vision guidance system that is cost-effective. Vision guidance system distinguishes the landmark or guide line from the input image from AGV camera and uses this landmark to guide the AGV. In the past, problem associated with computer processing time of vast amount of image information was the major stumbling block in choosing the right model. However, in recent days, the difficulty in this area has seen major improvement due to the advances of computer technology [3-5].

After the AGV based on optical guidance system obtains images from mounted camera, images get decomposed and feature guidelines and landmarks from the surround environment are identified using image transformation routine. However, due to the limitation inherent to the camera in its ability to resolve different elements of images at varying brightness of the light, some information within image is lost. This paper proposes a noble vision guidance system less affected by disturbance factors caused by different brightness of the light. To achieve this goal, darkroom environment is designed and set up in such way uniform brightness level is maintained throughout the room. The type of controls established for the driving are P control, PI control and PD control. However, they each have the problem. Therefore, the driving control method has been used mainly PID control that integrated advantages. However, PID control method is simple structure and efficient in the linear system, whilst that is difficult to apply in nonlinear environment and varying System. In this paper, optical guidance system using ANFIS(Adaptive neuro-fuzzy inference system) is proposed for effective driving control of AGV according to the driving line to the rapidly changing.

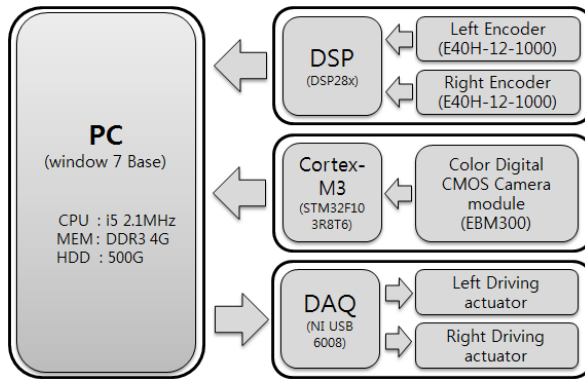
ANFIS commonly is used to optimization in control and prediction because it is possible function approximation of input value and output value. Proposed method measure guide line in acquired image from camera with AGV and then it input to ANFIS calculated center error of AGV and inclination. It learns input value using hybrid learning method and control drive of AGV through output value.

## 2 Model of Vision Guidance System

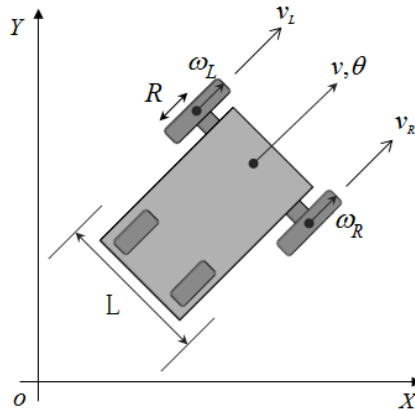
To verify the proposed method, we designed the simulator of AGV based on vision system as Fig. 1.

Driving method of the AGV model is to use differential wheels that speed difference of two wheels decides to drive AGV whether in a straight line or around a curve. This AGV is controlled after acquiring image that has a constant brightness. However, a general image has a problem of light disturbance which is disadvantage of the camera. To minimize the problem, a camera is equipped with a darkroom in this paper. The kinematic analysis of AGV's movement is required for driving control of AGV. Figure2 shows the analyzed kinematic model of the used AGV.

In Fig. 2,  $W_L$  and  $W_R$  are angular velocities of each wheel that were calculated from encoders on the AGV.  $v_L$  and  $v_R$  as linear velocities of each wheel can be derived by Eq. (1) that is composed of angular velocity of each wheel and the wheel radius.



**Fig. 1.** System configuration of used AGV



**Fig. 2.** Kinematics of experimental AGV

$$v_L = \omega_L \times R, v_R = \omega_R \times R \quad (1)$$

Linear velocity of AGV can be calculated by Eq. (2) that is composed of values obtained from a breeding Eq. (1).

$$v_k = \frac{v_L + v_R}{2} \quad (2)$$

Angular velocity of AGV can be obtained by calculating Eq. (3) is composed of  $L$ ,  $v_L$  and  $v_R$ .  $L$  means the rotation axis of left-wheel to rotation axis of right-wheel the distance.

$$\Omega_k = \tan^{-1} \left( \frac{v_R - v_L}{L} \right) \quad (3)$$

Using the angular velocity, linear velocity of AGV has moved to distance and angle of Eq. (4) is shown in.

$$\begin{bmatrix} x_{k+1} \\ y_{k+1} \\ \theta_{k+1} \end{bmatrix} = \begin{bmatrix} x_k + v_{Lk} \times \cos(\theta_k + \Omega_k) \\ y_k + v_{Rk} \times \sin(\theta_k + \Omega_k) \\ \theta_k + \Omega_k \end{bmatrix} \quad (4)$$

Eq. (4) can be used for controlling speed value of two-wheel, position value can be determined. Installed darkroom and optical in the actual AGV and the devices were manufactured miniaturization to facilitate mounting. Driving line is used for detection as shown in Fig. (3).

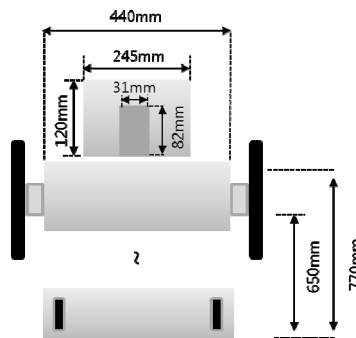


Fig. 3. Used camera module

### 3 Driving Control Method of Vision Guidance System

The AGV which contains the camera with darkroom has a short view, and the information of guidance line is changed quickly. Because of this, PID controller doesn't correspond with the control system which considers the error of the AGV's center position and the slope of guidance line. In this paper, to solve such problem, we proposed the driving control method of AGV using ANFIS algorithm [6-8].

### 3.1 Detecting Method of Guidance Line

To control accurately driving of the vision guidance AGV, both the current position of the AGV and target position are required. In this paper, we extract the current position of the AGV and the target position on the guidance line after detecting the guidance line from the image obtained by camera. Fig. 4 shows the detecting method which calculates center error of AGV and the slope of the guidance line.

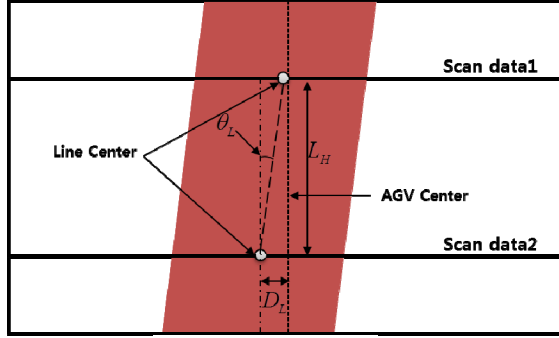


Fig. 4. The used method for detecting a guidance line

The center position error presents the distance between the center of the guidance line and the center of AGV, and the slope of a guidance line presents the slope of a guidance line based on the heading of AGV. The center position and the slope of guidance line are calculated by Eq. (5).

$$\theta_L = \tan^{-1} \left( \frac{D_L}{L_H} \right) \quad (5)$$

$$D_L = AGV_{center} - Line2_{center}$$

### 3.2 PID Controller

$$V_d = K_p (D_L + \theta_L) + K_i \int D_L dt \quad (6)$$

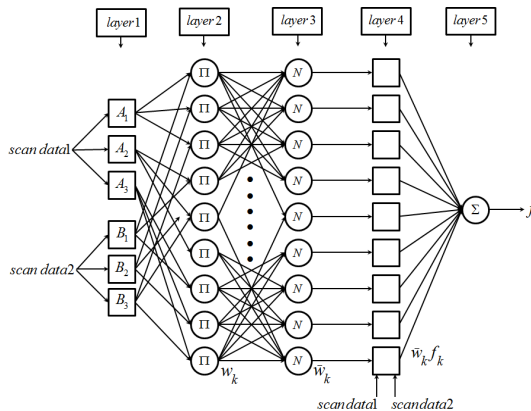
PID controller can be made by using center position and the slope of guidance line calculated from captured image. Eq. (6) represents about the equation for PID control used in the paper [9].  $V_d$  is velocity-difference on reference voltage related to velocity. Eq. (7) shows that  $V_d$  is used for calculating velocity of wheels on both side.

$$V_R = V_{reference} + V_d$$

$$V_L = V_{reference} - V_d \quad (7)$$

### 3.3 ANFIS Algorithm

ANFIS algorithm was proposed by Jang in 1993, it has excellent performance for function approximation. Recently, it was broadly applied to time series prediction and system control. Optimization methods of ANFIS parameters include gradient training method and hybrid training method. In this paper, hybrid training method which is a combination of different two training rules is used instead of gradient method that is slow and has highly possibility converged at local minimum. Hybrid training method optimizes conclusion parameters using LSE algorithm at forward-direction training and optimizes conditional parameters using Gradient descent method at backward-direction [10]. Fig. 5 show overall configuration of ANFIS.



**Fig. 5.** Structure of ANFIS

Rule1 : if SD1 = M, AND SD2 = M, then  $z = 0.0003799 \cdot SD1 + 0.01567 \cdot SD2 - 0.07959$   
 Rule2 : if SD1 = M, AND SD2 = L, then  $z = -0.01267 \cdot SD1 + 0.03142 \cdot SD2 - 0.6641$   
 Rule3 : if SD1 = L, AND SD2 = M, then  $z = -0.01268 \cdot SD1 - 0.006715 \cdot SD2 - 0.2415$   
 Rule4 : if SD1 = L, AND SD2 = L, then  $z = -0.001255 \cdot SD1 - 0.009251 \cdot SD2 + 0.7071$   
 Rule5 : if SD1 = VL, AND SD2 = M, then  $z = -0.04593 \cdot SD1 + 0.141 \cdot SD2 - 2.67$   
 Rule6 : if SD1 = VL, AND SD2 = L, then  $z = 0.007312 \cdot SD1 + 0.05564 \cdot SD2 - 2.077$

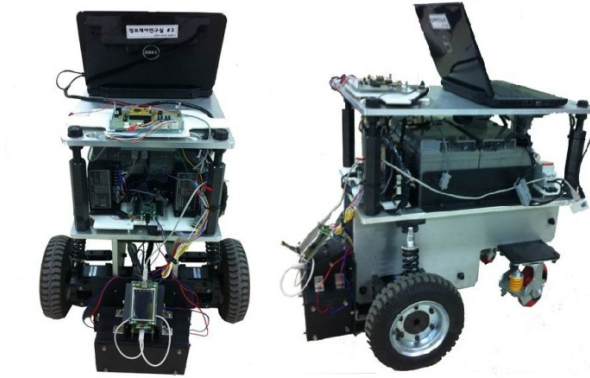
**Fig. 6.** If-then rule of Sugeno type

If-then rules of used ANFIS are shown in Fig. 6 where SD1 is center position and SD2 is angle of guide line. Data are linguistic variables that has next set {M(middle),L(left),VL(very left)}. Z is input value of double wheel for SD1 and SD2. In this paper, training data are scan-line data and velocity-related voltage gap as input-output data of ANFIS. It is attained by driving AGV through PID control.

## 4 Experimental Result

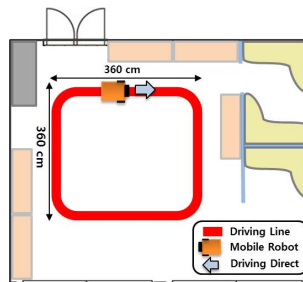
### 4.1 Experimental Environment

To experiment, we installed two cameras in front of AGV as Fig. 7. First camera slantingly is installed to control PID. Second camera is installed in dark-room to vertical direction from ground.



**Fig. 7.** Experimental AGV

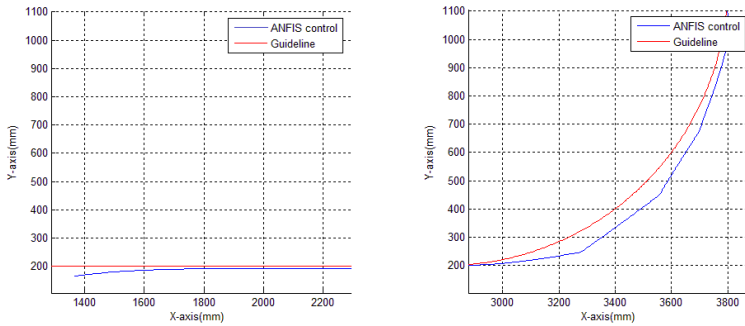
Experiment space is 360 cm  $\times$  360 cm. We attached guide line as Fig. 8 and were driving AGV at the speeds of about 16 cm/s. In addition, Experiment separate to get learning data and to recognition learned algorithm.



**Fig. 8.** Experimental environment

### 4.2 Extraction of Learning Data

Experiments are conducted on the same guidance line as PID controller's through the simulation what we designed. The driving result of proposed method is shown in Fig. 9.



**Fig. 9.** Experimental result

Table 1 shows max value of the error distance and error angle in curved drive which proposed method is applied to.

**Table 1.** Performance of ANFIS control

	Traveling angle	Error of the AGV's center
Max	15.18 degree	38mm

Experimental results show that proposed method can drive stably without the derailment.

## 5 Conclusion

This paper presented the guidance method of AGV using vision guidance system. To develop the vision guidance system, we designed and used the AGV of differential driving type and the camera module. To reduce the disturbance from the brightness of the light for the weakness of the camera, we used the darkroom to detect the guidance line. To track the quickly changed guidance line on the driving effectively, ANFIS algorithm with hybrid learning algorithm is used for the driving control. We analyzed the performance of proposed method through the simulator with the modeling of AGV after the learning that used the measured data based on the PID controller. The experimental results based on the curve-driving which is occurred the most error, we verify the result that proposed method enables AGV to drive stably with reducing the error and no derailment.

**Acknowledgments.** This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the Human Resources Development Program for Specialized Navigation/Localization Technology Research Center support program supervised by the NIPA(National IT Industry Promotion Agency) (NIPA-2012-H1502-12-1002).



## References

1. Dogandzic, A., Riba, J., Seco, G., Lee Swindle-hurst, A.: Positioning and Navigation with Applications to Communications. *IEEE Signal Proc. Magazine* 22(4), 10–11 (2005)
2. Le-Anh, T., De Koster, M.: A review of design and control of automated guided vehicle system. *Eur. J. Oper. Res.* 171, 1–23 (2006)
3. Vis, I.A.: Survey of Research in the Design and Control of Automated Guided Vehicle Systems. *European Journal of Operational Research* 170(3), 677–709 (2006)
4. Schulze, L., Wullner, A.: The Approach of Automated Guided Vehicle Systems. *Service Operations and Logistics, and Informatics*, pp. 522–527 (2006)
5. Crowley, J.: Navigation for an intelligent mobile robot. *IEEE Journal of Robotics and Automation*, 31–41 (2002)
6. Kim, Y., Kim, S., Lee, K.: Auto Steering Control of Unmanned Container Transport(UCT) with Vision System and Cell-Mediated Immune Algorithm Controller. In: 30th IECON, vol. 3(2), pp. 2987–2991 (2004)
7. Butdee, S., Suebsomran, A.: Automatic Guided Vehicle Control by Vision System. *Industrial Engineering and Engineering Management*, 694–697 (2009)
8. Lee, Y., Suh, J., Lee, J.: Driving control of an AGV for an automated container terminal using an immunized PID controller based on cell-mediated immunity. *Artificial Life and Robotics* 9(2), 90–95 (2005)
9. Lee, J., Kim, J., Lee, Y., Lee, K.: A Study on Recognition of Lane and Movement of Vehicles for port AGV Vision System. In: *Proceeding of the 2002 IEEE International Symposium on Industrial Electronics*, vol. 2, pp. 463–466 (2002)
10. Jang, J.-S.R.: ANFIS: Adaptive-Network-Based Fuzzy Inference System. *IEEE Transactions on Systems, Man and Cybernetics* 23(3), 665–685 (1993)